Flight Test Results of the Head-Up Synthetic Vision Display

For the
Quarterly Review of the NASA/FAA Joint University Program for Air Transportation Research
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Project Sponsor: Joint University Program

Introduction

- General Aviation instrumentation has undergone little change in the past 50 years.
- Major advancements have been made in the areas of inertial navigation and high accuracy GPS.
- VMC into IMC flight continues to be one of the two major areas producing the largest number of GA fatalities.
- On average one spatial disorientation accident occurred every eleven days from 1987 to 1996.

Overview

- Motivation Behind Head-Up Synthetic Vision Display (HUSVD)
- Modern Synthetic Vision Systems vs. Prototype Display System
- Prototype HUSVD System Overview
- Flight Tests
- HUSVD New Architecture
- Attitude and Heading Reference System (AHRS)
- Multi-View HUSVD

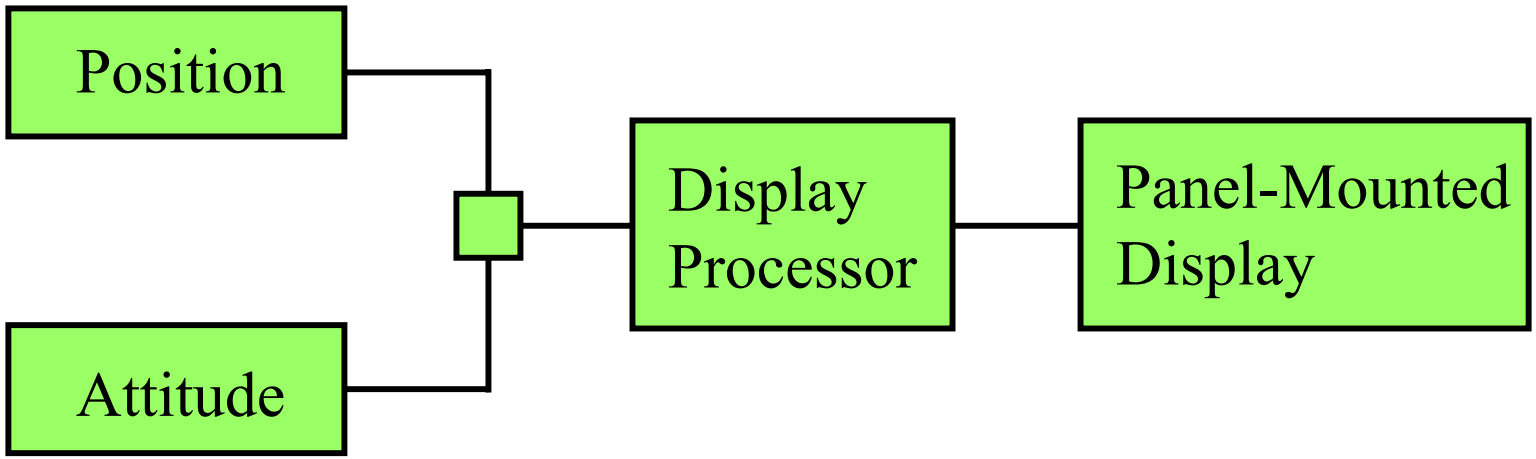
No Longer Known as the eHUD

- Enhanced Vision Often Refers to a System that Incorporates Some Type of Infrared Sensor or Thermal Imaging Sensor to Augment a Virtual Display
- Head-Up Display or HUD Often Refers to a Collimated Symbolic Display
- The Head-UP Synthetic Vision Display (HUSVD) System is Neither Enhanced or Collimated

Motivation Behind HUSVD

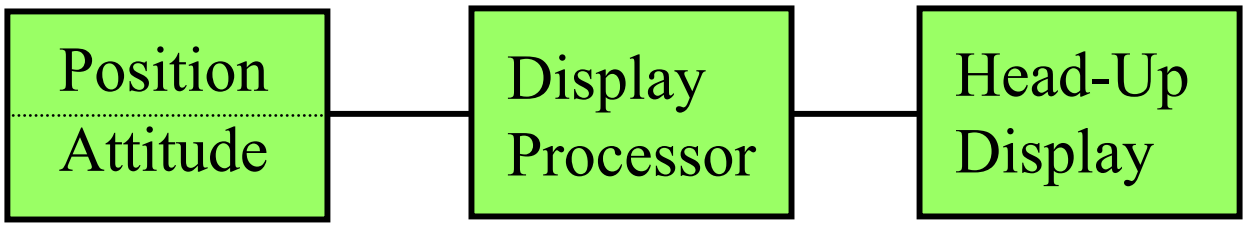
- Provide Visual Cues in IMC
- Increase Situational Awareness in IMC
- Reduce Pilot Training and Currency Requirements for Flight in IMC
- Reduce Instrument Fixation During the Approach
- Cost-Effective Head-Up Synthetic Vision Display

Typical Synthetic Vision System Architecture



- **Aircraft Attitude Sensor**
- **Aircraft Position Sensor**
- **Display Processor**
- **Panel-Mounted Display**

Prototype HUSVD System Architecture



- **Attitude/Position Sensor**
- **Data Processor**
- **Head-Up Display**

The prototype HUSVD was flight tested on th 18th of July 2002

Pseudo-Attitude Determination

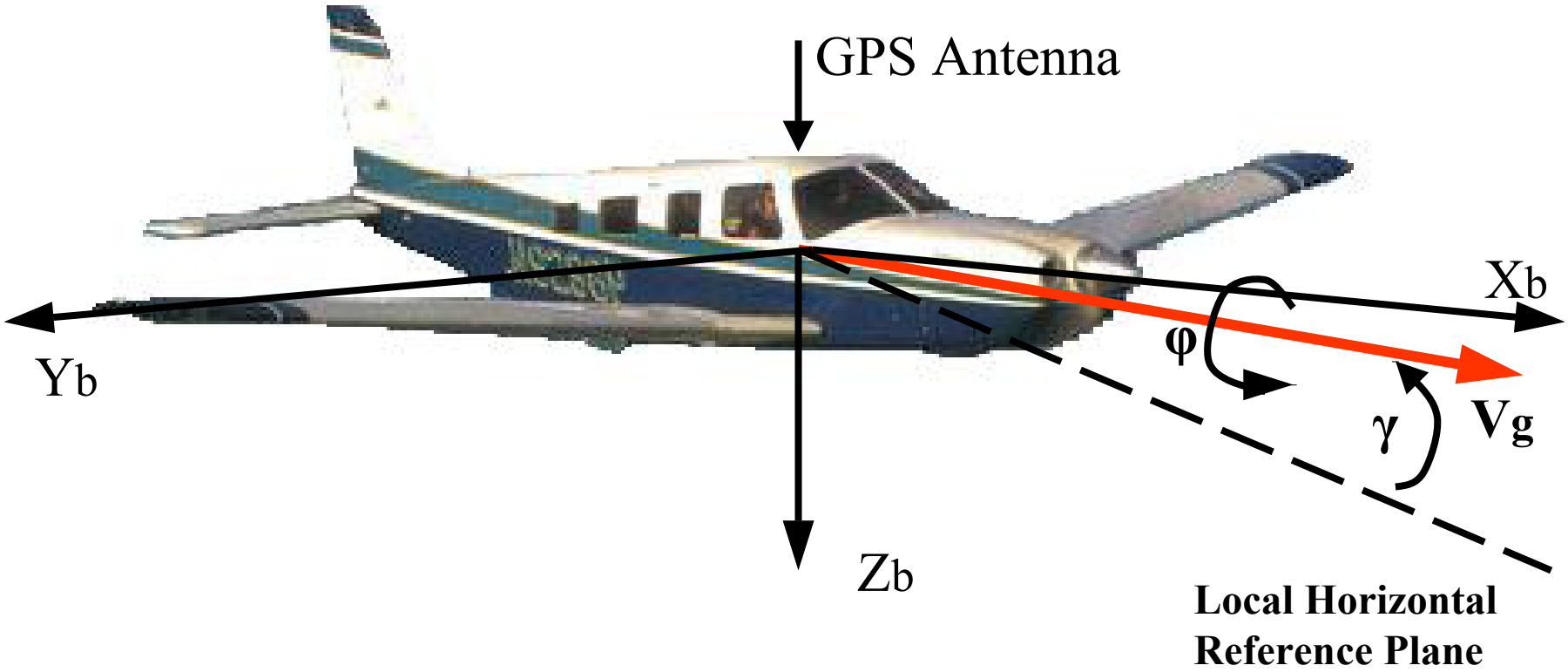
(*Velocity Vector Based Attitude Determination*)

Developed at the Massachusetts Institute of Technology by:

- Dr. Richard P. Kornfeld
- Dr. R. John Hansman
- Dr. John J. Deyst

The information on the following slides, regarding Velocity Based Attitude, was taken from "***The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture***" Report No. ICAT-99-5, June 1999.

Pseudo-Attitude

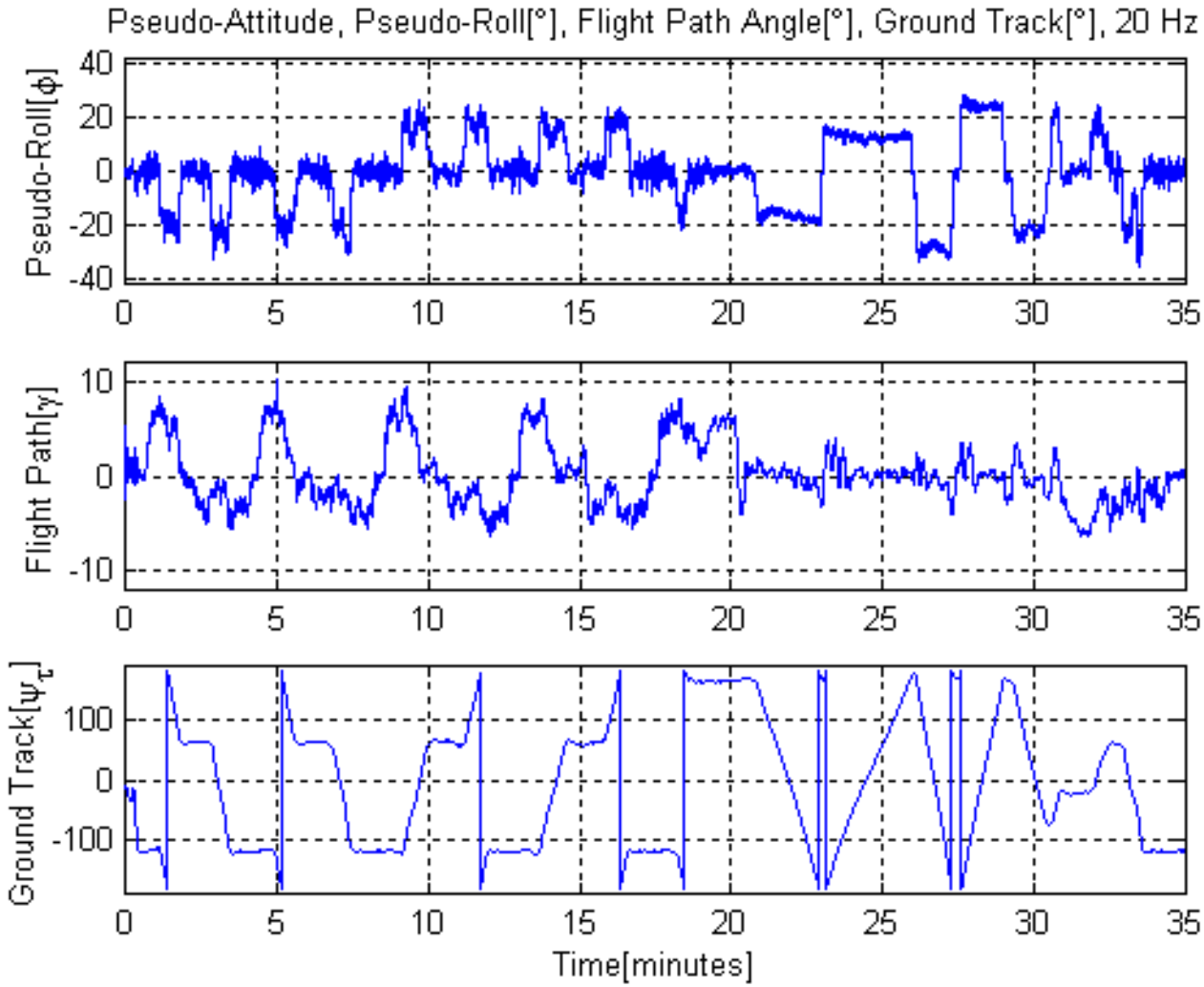


Flight Path Angle : γ

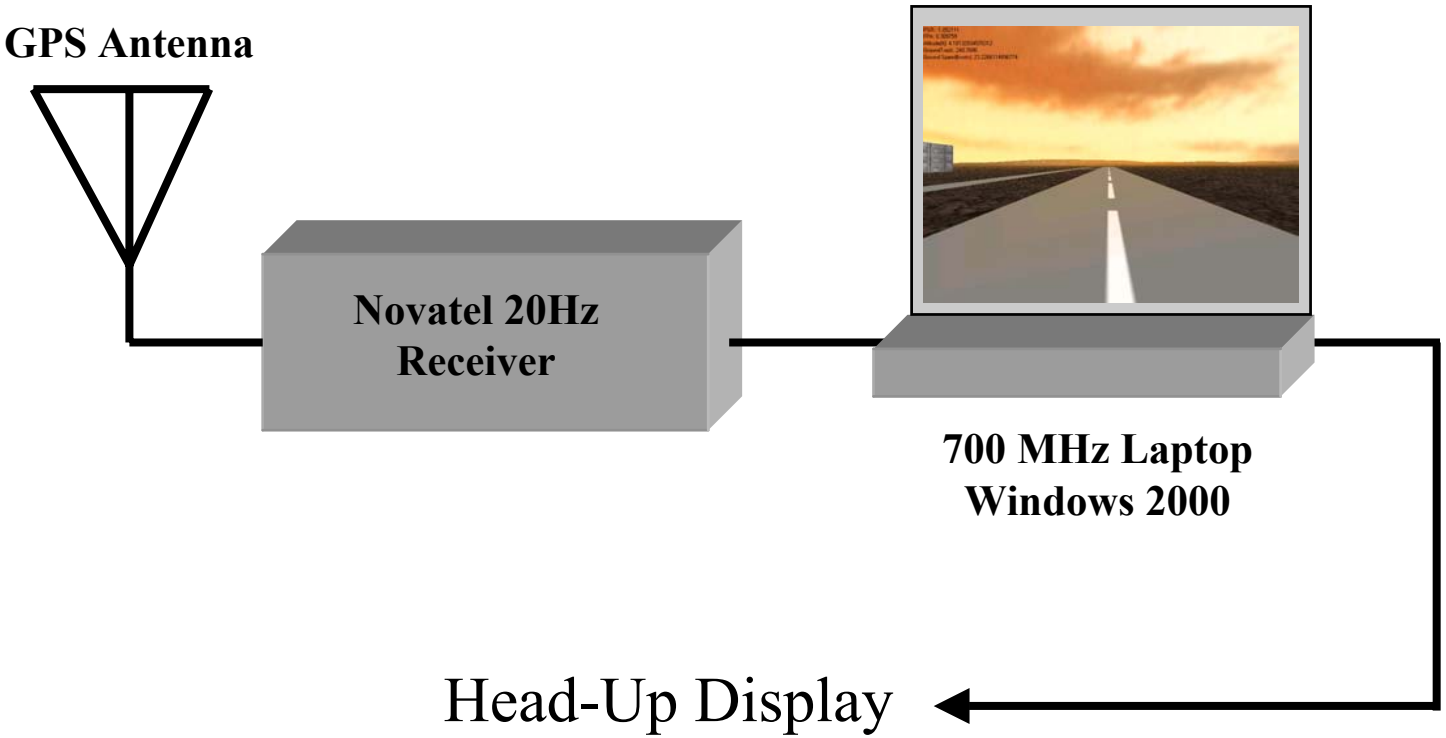
Pseudo-Roll Angle : φ

FB: Body-fixed orthogonal axes set which has its origin at the aircraft center of gravity.

Pseudo-Attitude Over Time



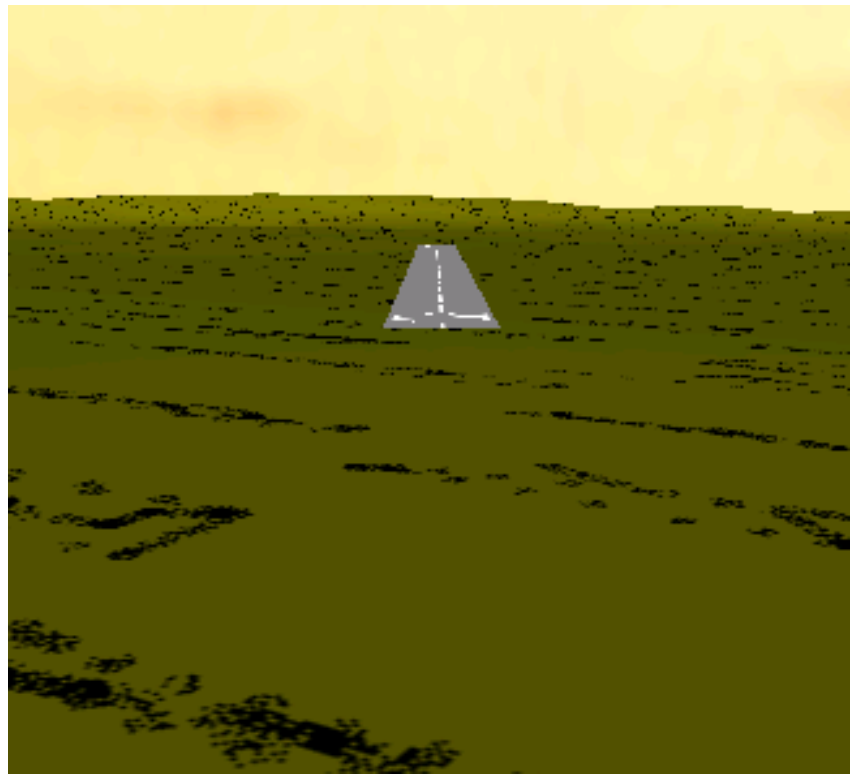
Current eHUD Configuration



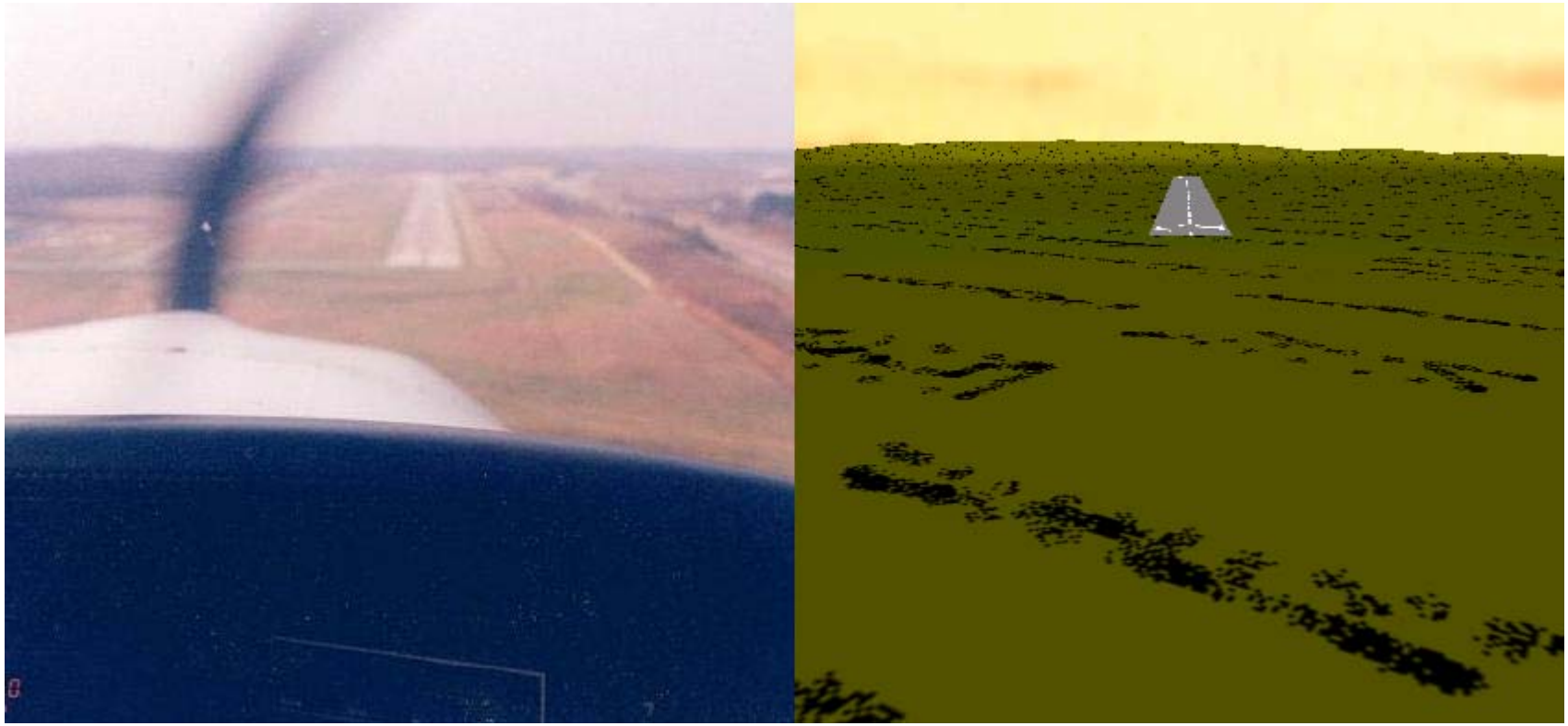
Data Processor and Display Processor

- 700 MHz Laptop Running Windows 2000
- Attitude Determination Algorithm Performed in C++ DLL
- Display Written in Visual Basic
- Graphics Produced Using Revolution 3D Graphics Engine
- Three-Dimensional representation of the outside world

Image Layers



Synthetic Vision Comparison



Two separate test flights on UNI Runway 25. There is a slight altitude difference between the two approaches. Synthetic perspective is very compelling.

Flight Test Aircraft

Combiner Material: Lexan 9034

Projector Mounting

Equipment Installation

HUSVD: Climb-Out

HUSVD: Down-Wind Leg

HUSVD: Shooting Approach

HUSVD: Continuing Approach

HUSVD: Continuing Approach

HUSVD: Continuing Approach

HUSVD: Continuing Approach

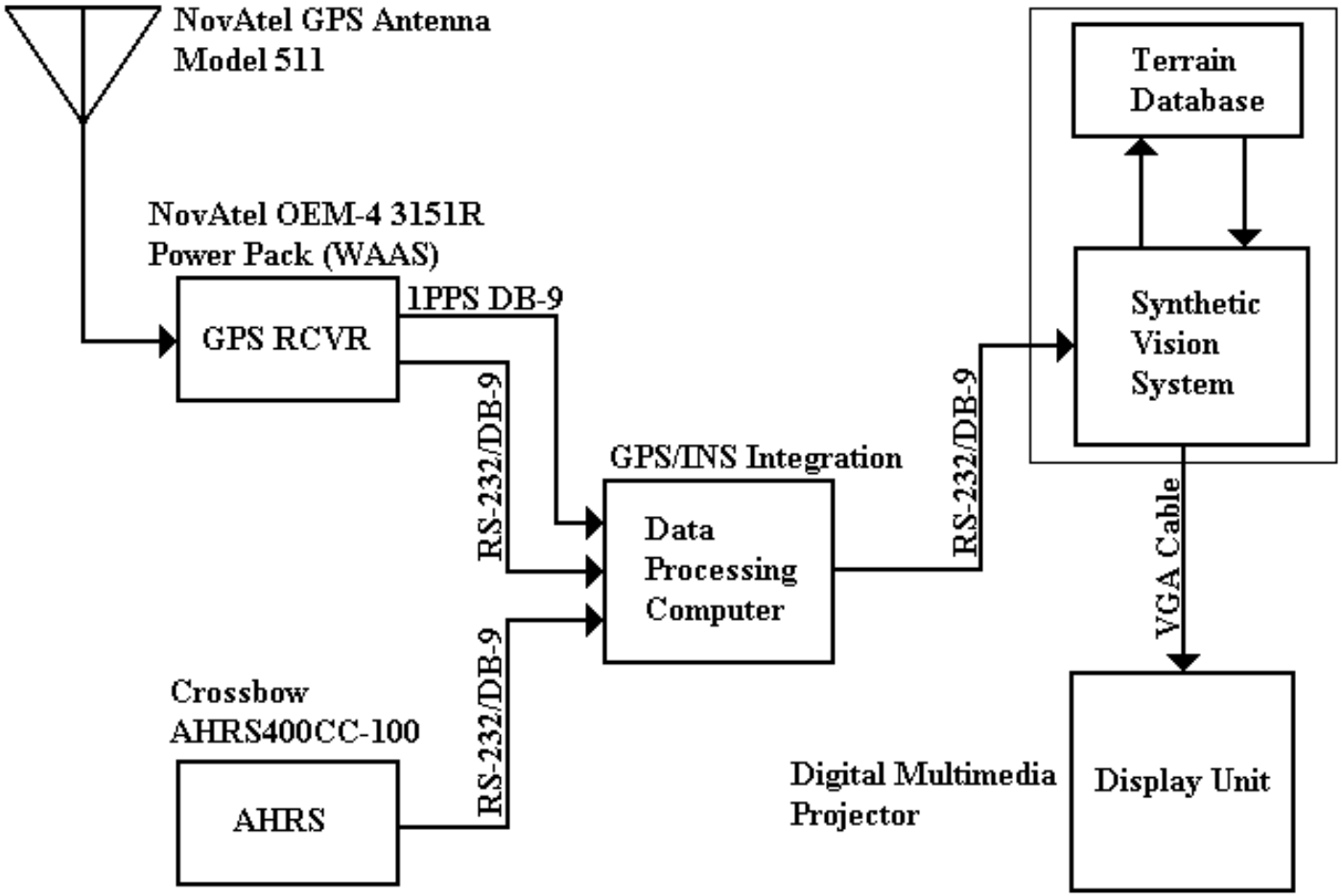
HUSVD: Before Touch-Down

HUSVD: Touch-Down

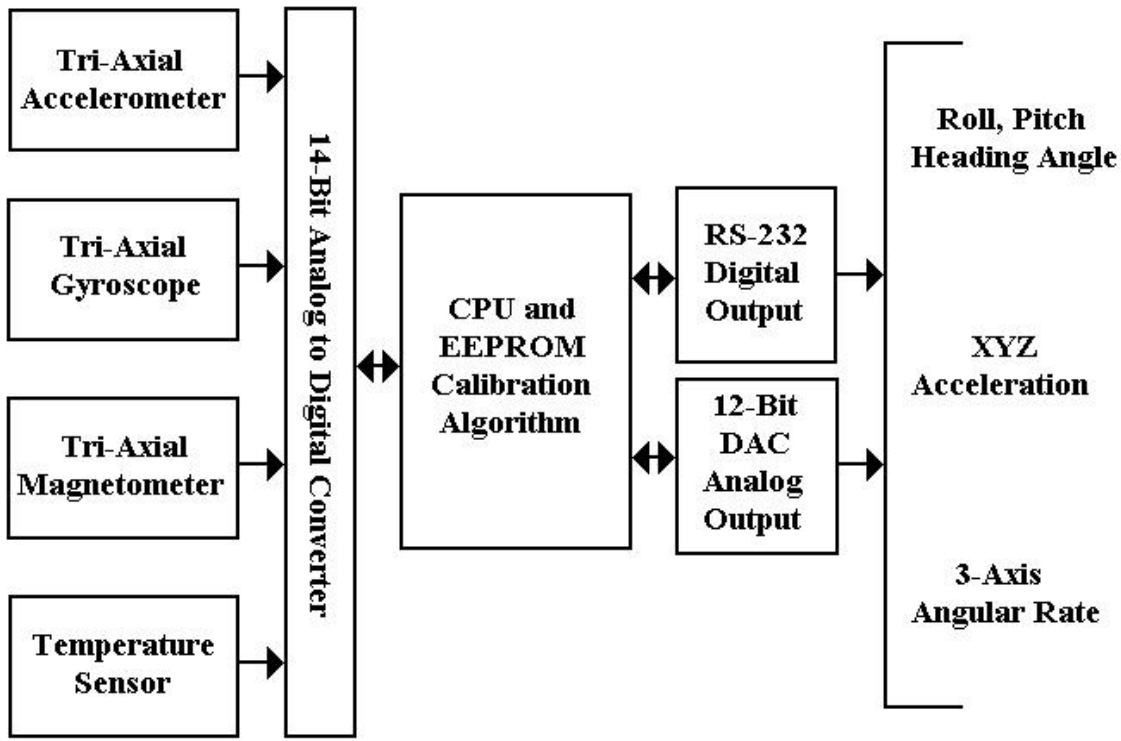
Lessons Learned

- Discrepancy in Size or Object Placement is an Immediate Distraction
- Synthetic Vision Head-Up and Head-Down Display Perspectives are Very Different
- Dynamic “Tuning” of HUSVD is Needed
- Object Size Needs to be Increased
- Lexan 9034 Promising Combiner Material
- LCD Projector Provides Navigation Quality Image in Various Lighting Conditions

New System Architecture

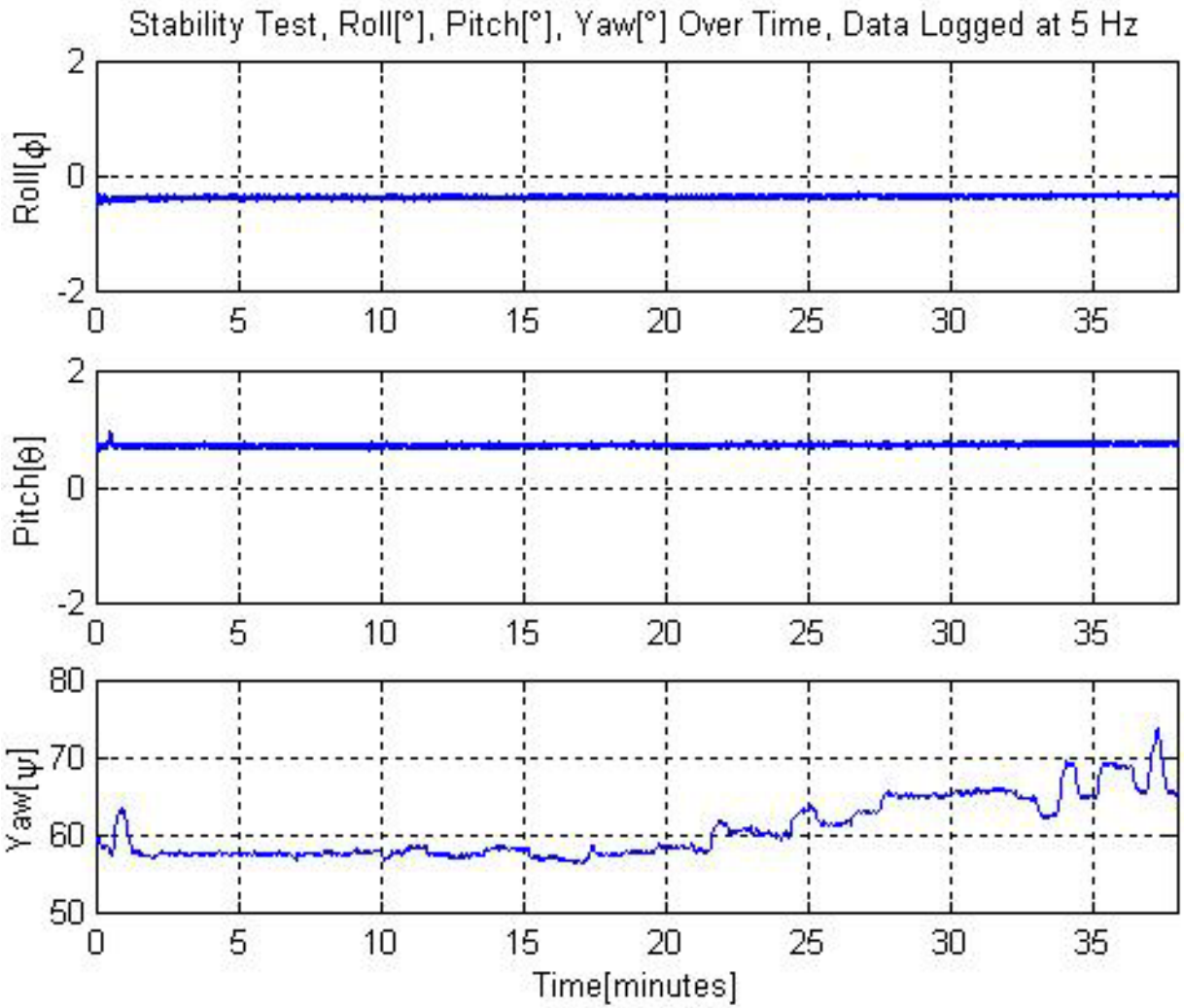


Crossbow AHRS400CC-100

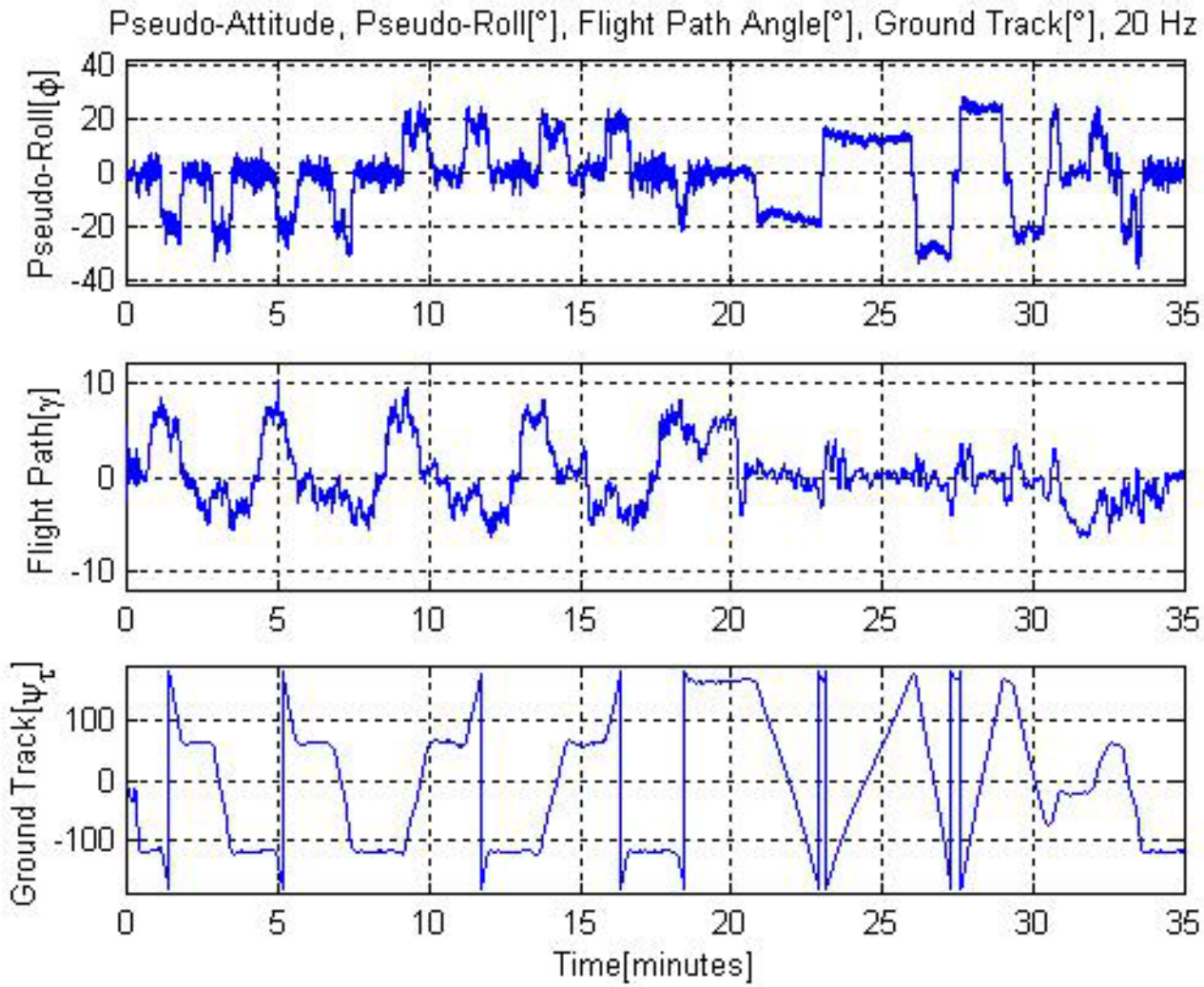


http://www.xbow.com

AHRS Static Evaluation



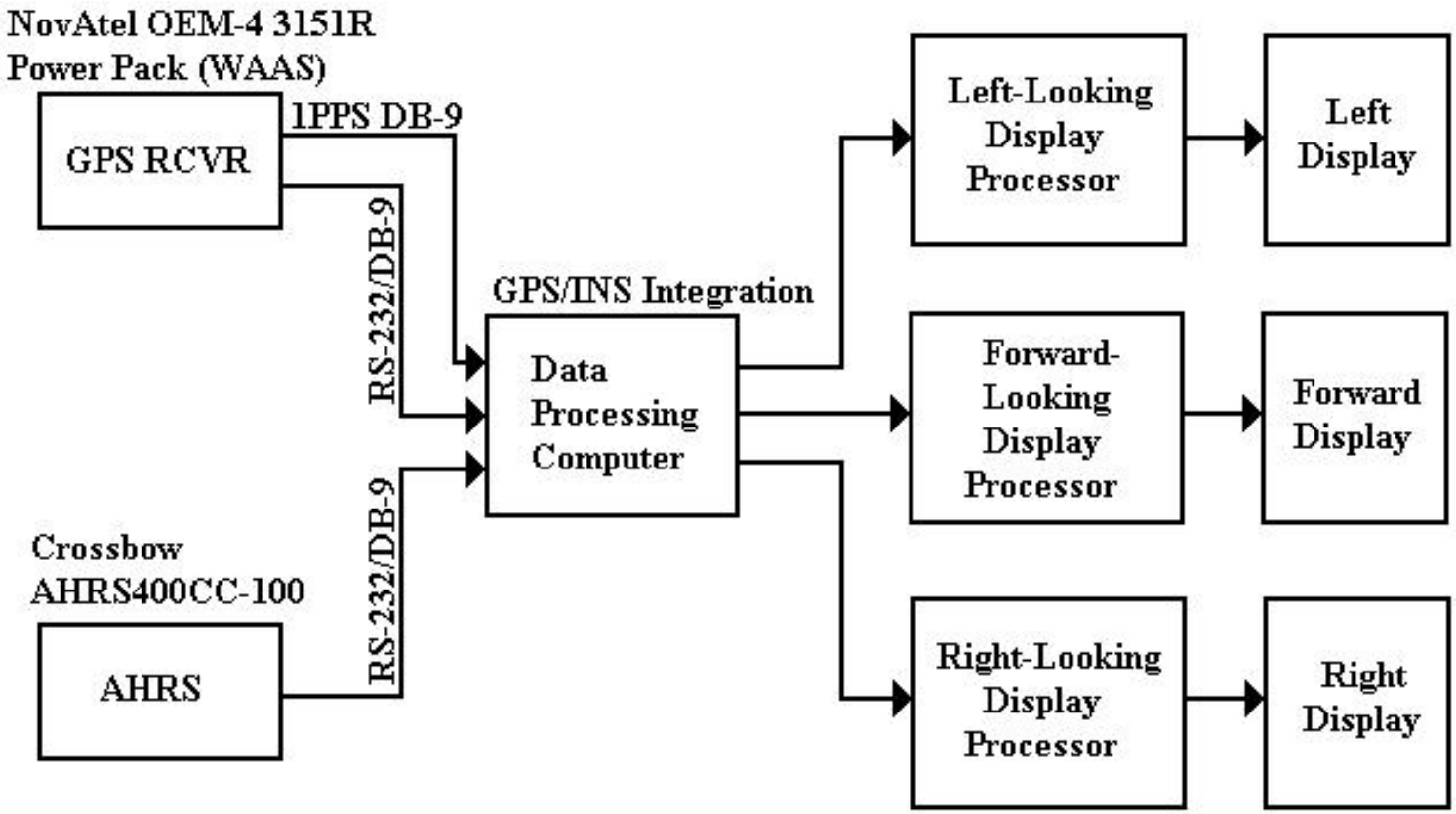
Velocity Vector Pseudo-Attitude



AHRS/GPS Integration

- AHRS Provides Robust Roll and Pitch
- AHRS Roll and Pitch will Drift Over Time Creating a Bias
- Complementary Kalman Filter will be used to Integrate the Single-Antenna GPS Attitude with the AHRS Measurements
- GPS Ground Track will be Used to Approximate the Yaw

Multi-View Head-Up Synthetic Vision Display System



Current Work

- Expand System to Include Both Forward-Looking and Left-Looking Views
- Flight Test in which Multi-View HUSVD is used to Navigate Aircraft from Climb-out to Approach
- Upgrade Synthetic Vision Software

Questions

References

- Kornfeld, R.P., Hansman, R.J., Deyst, J.J., *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture.* MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
- Jennings, C., Alter, K.W., Barrows, A.K., Per Enge, J., D. Powell, *3-D Perspective Displays for Guidance and Traffic Awareness.* Presented Sep 1999 at the ION GPS Conference, Nashville, TN.
- 1999 Nall Report, AOPA Air Safety Foundation, http://www.aopa.org
- Crossbow Technology, Inc. *AHRS400 Series User's Manual*, 41 E. Daggett Dr., San Jose, CA 95134, http://www.xbow.com

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